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Accommodating Science to External Demands: The Emergence of Dutch Toxicology

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Hybrid scientific fields consist of a collection of knowledge-producing and -utilising organisations, fulfilling a dual role of providing specific knowledge services as well as contributing to increased scientific understanding. In this article, the processes that govern scientific knowledge production in hybrid scientific fields are explored. While such sets of organisations are targeted in science policy as receivers of resources, as well as providers of services and other knowledge products, attention in science studies is all but lacking. Data from a study on toxicology as a representative of public health sciences are used. The author will focus on the effects on scientific research and its organisational relations by discussing three social processes relevant to knowledge production, problem choice, resource distribution, and reputational control.

Different commentators have observed that the manner in which scientific research is organised is changing. The institutional framework for choices in research is shifting from peer-controlled academic choices to allocation of funds through programmes and projects in which responsibilities for choice of research problems are shared with outsiders (Blume 1987; Geiger 1988; Rip 1990). Thus, scientific autonomy is significantly reduced or surrendered in externally coordinated mission-oriented institutes (Whitley 1984b). The current transformations in the conduct of science have been largely discussed in terms of policy and normative concerns about such institutional changes.[1] A major conclusion has been that academic research is, to an increasing extent, attached to social or economic problems.[2] Three important factors help to explain this shift. First, these changes have an internal origin, especially in the natural sciences, as crucial instrumentation became more costly

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and had to be shared to a larger extent. Therefore, changes take place at the level of fields or specialties of science, but such reasons do not hold for all fields of scientific inquiry to the same degree (Gillmor 1986). A second major reason resides in contextual changes. Policy needs formulated by corporations, state agencies, and others promoted scientific research in various new settings.[3] These changes led to a motley collection of research programmes, research centres, commercial research and development (R&D) firms, and scientific institutes to accommodate science to the demands posed by technological innovation and the solution of social problems. An increasing number of scientists, therefore, face organisational constraints on problem choice.[4] Third, scientists not only reacted to external interference, some groups of scientists also proactively engaged in efforts directed at organising science for social and economic goals (Fujimura 1988; Studer and Chubin 1980). Thus, changes in the research system may be attributed as well to a more entrepreneurial attitude of scientists and cannot be analysed exclusively as a unidirectional process (e.g., the influence of external pressures or funding) (Cozzens 1986). The combination of these three processes can be summarised broadly as a significant change of the relations between research system and the social environment (Rip 1990).

The type of organisational changes indicated above can be expected to have an impact on several aspects of the production of scientific knowledge, such as the division of tasks, work organisation, and choice of research problems that together constitute the core of the research process. In sociology of science, it has been recognised that insight in the manner in which scientists choose research problems can help in interpreting the dynamic character of science. One of the positions put forward by Zuckerman (1978) and Gieryn (1978) is that scientists, in their choice of problems worthy of research, follow the lines that are imminent after they have chosen to follow a specific theory. From the discussion on the setting of research agendas in toxicology, a different picture emerges that does not suggest that the above insights are wrong or mistaken but adds a condition to it.

The manner in which scientists relate to problems is a significant issue in the Mertonian approach to science because theory accumulation is the ultimate aim of science and therefore a relation between choice of research problems and choice of theory is important. Changing patterns in science are related to new areas of theoretical excitement and, therefore, to the internal history of such scientific areas (Zuckerman 1978, p. 85). These changes at the field level are partly a consequence of scientists changing the problem sets on which they work. By adding new problems and dropping old, scientists migrate from one area to another. Because in this set of explanations, control of problem sets is in the end internal to science, the question of how problems relate to external resources is ignored. The relation between problems and resources can be regarded as one of the main issues in laboratory studies. In Latour and Woolgar (1976), the activity of scientists is considered to be an activity that attracts external resources and secures their future supply according to a "credibility cycle" (p. 201). Fujimura (1987) argued that internal changes are intrinsically related to the wider social environment. Specific research approaches require commitment of resources, which must be secured from outside organisations (Fujimura 1987). To make this support possible, these external organisations must become interested. In her perspective, which is close to Callon's approach, external interests have to be translated into the interests of the researchers (Fujimura 1987; Callon 1980, pp. 197-219).

The analysis of applied sciences has led on one hand to a debate on the preferred mode of operation of scientific systems, as discussed in the introduction, and on the other hand, to discussions on the preferred ways to solve social problems (Morone and Woodhouse 1986). In addition, the role of the state in mediating between these two conflicting demands has been analysed.[5] However, such studies take a "helicopter" view of these relations. Attention to regularities in integrative mechanisms at the level of actual research is lacking. From the analysis of toxicology, the following more detailed picture of the integration of science with policy, through problem selection, is apparent.

Origins of Toxicology

A number of different concerns have shaped the field of toxicology over the past two centuries. Attention to occupational problems in nineteenth-century industrialisation was complemented by early regulation of health risks of pesticides and drugs. The regulatory trajectory was completed by the increasing attention toward environmental effects of chemicals in the second half of the twentieth century, resulting in general rules for the admission of new chemicals to the market. Currently, toxicology is a field of science and practice that is concerned with the scientific evaluation of risks of chemicals to humans and the environment. The societal importance of the field has steadily increased in the past half century. Toxicology institutionalised in connection with decision making on health and environmental problems. Recently, this relationship has been referred to as a "shotgun wedding" (Davis 1985) between environmental law and regulation and environmental science. Science-forcing requirements have been introduced in the 1950s, such as the zero-cancer-risk requirement formulated in the Delaney clause to the Food and Drug Act of 1956. In the 1970s, environmental laws authorised agencies to take regulatory action on the basis of scientific inquiry (Davis 1985). The mechanisms through which these concerns have shaped toxicology are slightly different with regard to national characteristics (Brickman, Jasanoff, and Ilgen 1985) as well as practical questions (Jasanoff 1990). Integration of national, political, and juridical concerns takes place, leading to localised fields that differ significantly in relevant dimensions influencing the issues that concern toxicologists. This results in different domains, specified by social practices, such as occupational and environmental hygiene; scientific disciplines, such as biochemistry, pathology and analytical chemistry; and national policy concerns. These variations result in a number of differently structured opportunities for toxicology to operate in.

Increased government regulation to protect humans, animals, and the ecosystem from adverse effects led, during the past fifty years, to pressures on toxicology to provide scientific data. The main social actors that are interested in data from toxicology are state agencies such as, in the United States, the Food and Drug Administration, the Environmental Protection Agency, and the Occupational Safety and Health Administration; in addition, industry, mainly the chemical and pharmaceutical industry, has an active interest. The primary interest of these audiences is the production of applicable knowledge that is trustworthy enough to base policy and management decisions on (Mukerji 1989).

The combination of various external demands mentioned above induced a research field based on practical questions, which are usually significantly different from those in discipline-oriented research. Therefore, compromise has to be sought between scientifically justifiable model systems and observations in real systems. For example, biologists with an interest in adverse reactions of biological organisms to chemicals prefer to work with simple model systems related to theoretical questions. The regulatory drive, a result of frequent mishap in the field of drugs, pesticides, and chemical production, formed a support system for scientists with various disciplinary backgrounds that were willing to attack these messier problems. Thus, in the early days of toxicology, scientists were attracted to research on practical questions not directly related to the internal reputational system of science. External nonscientific audiences had a need for knowledge that was increasingly embedded in the context of binding regulatory rules. Both government agencies and industry defined what the testing for adverse effects of chemicals should be. Therefore, allocation of resources and the enhancement of local reputations increasingly rewarded orientation toward questions of practice.[6]

The following story illustrates the interaction between regulation and scientific research. In the 1960s, when toxicology was underdeveloped with regard to questions about effects of chemicals in ecosystems and other species than humans, Rachel Carson's (1962) book *Silent Spring* acted as a catalyst for drawing public and government attention to this area. One instance of this influence provides a vivid illustration of the processes involved. In England, biologists at the Nature Conservancy were well aware of the problems described by Carson. They lacked the support, however, to build a research program to prove their suspicions. The publication of Carson's book was used to press the government into action. The biologists involved were careful to introduce their own interests as necessarily linked to the state. "If the government wanted to be in a position to assess accurately the emotional biased generalisation made by both sides, there had to be much more research" (Sheail 1985).

To achieve this goal, they organised a lobby behind the scenes and argued in a way that was politically useful, though not necessarily targeting the most damaging chemicals. An example is the emphasis put on the loss of wildlife for hunting purposes based on accounts (Sheail 1985) of landowners.

> In the opinion of the Conservancy's deputy director, Barton Worthington, the Conservancy could once again "afford to sit back and be dispassionate." The time was right for reassessment, and the Conservancy should seize the opportunity presented by "Silent Spring" to secure more resources so that an adequate appraisal could be made. (Pp. 89-90)

While the core of modern toxicology is tied to the interests of the state and of industry, these interests do not unequivocally dominate toxicology. Other practical purposes have also formed the focus for organisation. To elucidate the manner in which science and social problems are interrelated, I will use regulatory toxicology and state-science interaction as important examples here.

Increased attention to the adverse effects of chemicals on human and other organisms gave rise both to increased facilities for regulatory research and to growing interest in fundamental studies of mechanisms of toxic action. Not only did the amount of toxicological testing expand, the range of effects studied also broadened. As a result of both types of changes, the increased span of regulatory action and the increased attention from academic researchers, the field has changed considerably (Johnston 1980) in a short period of time.

> There can be little argument over the extent to which this research is constrained and directed by the political issues associated with risk determination and control. It is then, *par excellence*, a field in which organisational pressures and political objectives shape the selection, production and evaluations of scientific knowledge and its study can contribute to the development of more

> comprehensive theories of the interaction between political and intellectual aspects of the social reality which constitute science. (P. 104)

Two social processes that affect the conduct of scientific research warrant closer attention, and they will be drawn from the case study of the development of the Dutch field of toxicology. These are, first, the establishment of local credibility and, second, the institutional mechanisms that subsequently function to stabilise an area.

First, to determine the question whether toxicologists can be considered competent to answer social questions, it is crucial to examine in which way toxicologists can influence the precise definition of the problem for which their involvement is required. Thus, both at an individual level as well as the societal level, toxicologists depend on the ability to convince outside groups of the essential role of toxicologists.

Second, with regard to reputational control, the origins of the discipline and its links with social practice strongly suggest that its success or failure will not be judged by improvement on or extension of elegant theory but by the way in which social problems can be avoided or ameliorated. But such processes are never easy or lead to clear-cut answers. Therefore, toxicologists are in a position to obtain resources when they establish credibility with the social groups confronted with chemical hazards. Directly accessible nonscientific audiences thus execute the reputational control of toxicological research to a large extent. The discipline's resource base is dependent on its usefulness in addressing problems in society.

Problem Choice and Agenda Setting

In this section, I will delineate three mechanisms by which scientists can relate their research abilities with external audiences; these mechanisms have implications that reach beyond previous discussions of problem choice in science.

The first mechanism, used by scientists to integrate science and policy, consists of a form of piggybacking on a social problem. In this variant, the rhetoric of the arguments is that an audience can save money by spending it on toxicology instead of spending it on cleanup. When cancer tests suggested that formaldehyde was a possible cancer-causing chemical, public health authorities needed to decide whether they would remove formaldehyde-containing products from the market or remodel houses containing, for example, chipboard with formaldehyde base glue. As one of the toxicologists (Groenewegen 1988) argued,

> I was doing those tests on acetaldehyde when publications appeared in 1980 about nasal cancers appearing in formaldehyde-exposed rats. In the same period, we observed larynx tumours in hamsters. The newspapers were full of rumours on formaldehyde gas in houses and it was argued that those houses had to be rebuilt. I approached officials of the ministry and said to them "You have got a problem with formaldehyde. We have the expertise. If we could show that acetaldehyde does the same—and we already have indications that acetaldehyde induces tumours in rats—maybe we will be able to relieve you of this pressure." (personal communication, V. J. Feron, 7 August 1985)

Joining the policy bandwagon in this style affects policy options quite dramatically without affecting the research itself. It is therefore a boundary action directed at attracting resources to specific areas already in existence. The mechanism is exploited in various forms, but usually scientists are quite frank about their intentions and gains.

The second mechanism is the redefinition of an important social problem. In one of the toxicological research groups, immune-related toxicological research was conducted based on a few specific problems of pesticides, which were known to be caused by interaction with the immune system. The researchers actively tried to locate external problems for which their research would show the necessity to use immunotoxicological tests to prevent problems. When about 400 people died in Spain as a consequence of consuming contaminated olive oil, a relation was established between this problem, which lacked a chemical explanation, and immune toxicology.[7] The research group saw this as a problem—based on the reported symptoms—of the immune system and was very vocal in securing money to solve the mystery. The legitimacy of their action—they themselves argued—should be judged by the acceptance of their immunological explanation (personal communication, W. Seinen, 13 August 1983). It should be considered successful if their explanation was accepted socially and politically. In this sense, success would lead to redefinition of the problem in the terms of immunotoxicology, narrowing down the possible causation chain and involving scientific work in solving future mysteries.

Redefinition changes the content of a specific problem in an intricate manner. This mechanism focuses on positioning science in such a way that a link is established (cognitively, rationally) with an existing type of explanation. This mechanism also allows important external problems to be used as leverage within the field itself.

Third, an important mechanism consists of organised interactions between toxicologists and policy makers on relevant issues. This results in a hybrid scientific-political agenda. An example is the start of Dutch environmental toxicology. A hybrid group of toxicologists and policy makers founded the CNB (the committee on the assessment of side effects of pesticides) (Groenewegen 1987). The CNB provides a clear example of interweaving scientific and sociopolitical organisation along lines neither entirely centred on science nor on social concerns. The crystallisation point proved to be the concern for the environmental consequences of pesticides. One of the original starting points lay in the outcomes of research on the appearance of pesticides in certain disorders of water-related animals (mussels and birds). Concerned scientists and experts working in various ministries and companies came together and started the CNB on an informal basis. From this informal basis, anchoring points in the bureaucracy were constructed. In this congenial forum, negotiations on essential policy measures took place next to assessing the need to do additional research. In this process, both the scientific agenda and the political agenda were determined. Regardless of the name of the committee, it became clear that only some aspects of the so-called side effects of pesticides were thought to be important. Thus, ecotoxicological research was increasingly directed at other environmental contaminants, while the effect of pesticides on farmworkers were excluded. Thus, in the course of a few years, side effects of pesticides were no longer the central issue, and concern shifted to the effects of chemicals on the environment. This third mechanism demonstrates a form of collective, mutual structuring of agendas. A committee secures the resulting social mechanism—in fact establishing a place for more permanent exchange when compared to the other two examples above. The interaction still serves the processing of interactions between two different worlds (research and policy), but the roles of the experts are not neatly divided along these lines. As a result, the problems of research are directly put on the social agenda, and vice versa, social problems are directly related to research agendas.

Structured patterns of interaction between scientists and nonscientific groups involved in agenda-setting processes are not limited to the national level, a case in point being the complex of interactions surrounding regulation.[8] The regulatory agenda is determined largely outside the direct confines of local politics and local science. The influence toxicologists have on the regulatory agenda is largely indirect. Representatives from government agencies, industry, and academia meet regularly with toxicologists, and it is in such situations that mutual structuring of policy and research agendas takes place.

The first two mechanisms show a selection of problems, which not only takes the scientific merit but also the social importance of problems into account. The individual actions discussed here occur repeatedly and imply a close interrelation between social and scientific problem setting. The important point is that the regularity of such interaction is much greater than the microsociological analysis of science and technology suggests. The way in which coupling between the two areas occurs has been highlighted by the third mechanism. The actions in the institutional area between scientific and other organisations can be studied by giving attention to intermediate institutions, such as committees.

Generally, scientists cum advisers position themselves in ways that ensure involvement in both the definition and redefinition of a social problem as well as the determination of research agendas. The consequence of this behaviour suggests that the effectiveness of the scientific research will not be judged by interested colleagues (peer review) but by their perceived contribution to the solution of social problems. Defining a problem as a scientific/toxicological problem invokes expert judgment from the start and therefore ensures the involvement of toxicologists. Therefore, toxicology is effectively bound to external audiences. The definition of the scientific subject of toxicology has to be linked to the manner in which the social world defines problems with chemicals. When on this social agenda, toxicologists—to support their field of inquiry and training—secure resources, the focus may increasingly shift toward an internal reputational structure. The general strategy of toxicologists may be described as attentiveness to solutions to social problems of audiences, such as firms and government agencies, which cannot be solved with their own administrative or commercial knowledge and competence. The role of toxicologists for specific audiences therefore resides in the capacity of toxicologists to provide workable solutions for specific problems on a regular basis. Subsequently, much of the process of interaction on social and scientific issues takes place within a more general framework of institutional and broader reputational structures.

Reputational Control in Toxicology

In a field connected with social problems, an emphasis on scientific quality reinforces certain positions in the field at the expense of others. This problem has mostly been signalled from a societal perspective. By stimulating scientific research, fundamental solutions for problems would be reached, and local tinkering can be countered (Majone 1982). The emphasis in science studies on the functioning of peer review and reputations exemplifies this perceptive (Whitley 1984a). However, the discussion on scientific reputation puts far too much emphasis on the community aspect of scientific fields based on the positions of the sum of individual scientists in direct relation to their specialty or scientific field. In my opinion, the mediating influence of institutional surroundings are neglected. The organisational context has a farreaching effect on the reputation relevant for the scientist in his or her local field. The effect of reputational control in relation to the worldwide scientific fields is effectively mediated through these institutional positions to varying degrees. Furthermore, while the role of individual reputation as a resource might be important, at the level of research opportunities, financial resources are far more important. The division of such resources in fields such as toxicology takes place in a direct interaction with relevant audiences. I will discuss the mechanism of reputational control by nonscientific audiences on the basis of two (semicommercial and public) institutional positions I encountered in my case study. These examples could be augmented by reference to specific university groups from the same case study.

TNO-CIVO is a Dutch laboratory for food and nutrition research. The institute is partly financed by the government but earns most of its budget by contract and project money.[9] From a modest beginning, the institute has grown to a modest research facility with a couple of dozen fundamentally trained scientists. An increasing part of their research for external audiences is also promoted as scientific research. The question is how scientists are constrained in their work by organisational goals and culture and how they integrate changing availability of external resources and audience interests into their scientific work.

The commercial attitude of the institute's first directors resulted in an institute that relied partly on contract research.[10] Especially good contacts with industries in the food sector were established. This attitude of the management made its work dependent on changing industrial interests and its willingness to finance research. The general problems of industry with chemicals, the perceived opportunities by the CIVO management, and the availability of infrastructure led to the start of toxicological research and toxicity testing. CIVO could pursue toxicity testing and research because it was capable of organising food research on a commercial basis, it had the basic facilities for running animal tests, and it demonstrated willingness to serve industry as a customer.[11]

By following industrial needs, a broader basis for toxicity studies was created. This institutional strategy, based on resource dependence on industry, thus strengthened the research infrastructure. With these resources, toxicologists could acquire advanced equipment and support staff, which could, of course, also be put to other uses. Contract research requirements have led to expansion. This involved routine work but has also required a differentiation of expertise. Research done within the department changed considerably during this period. From beginnings in food research and toxicity testing, the programme has evolved toward large toxicological research projects, some of which are funded from bodies that have a principal role in the support of fundamental research. These various changes stimulated new research themes and suggested links with financial sources other than industry. Underlying it is the notion that contract research and scientific work need to reinforce each other. Thus, research was increasingly legitimated in both the scientific and industrial contexts. The new type of research that was organised consisted of projects centred on certain themes in which resources were sought to support a preconceived research plan.

Foreign industries were, and are, prominent among the customers of CIVO, although relations with Dutch industry have always balanced this. "The value of toxicological research increases with the reputation of the research-institute. This reputation increases with the fact that foreign firms also award contracts and thereby recognise the work of the institute" (De Groot 1974).

When customers are satisfied by the reports produced and public health authorities accept the reports, there is a good chance that new contracts will result for the institute. These contracts are not only obtained from the original customer, but industrial toxicologists have frequent contacts with each other and recommend the work done by contract institutes such as CIVO. The links with industry can thus be seen as providing a reputational structure that is, at the same time, nonlocal and nonscientific.

Change in the areas of interest of industry has an effect on the type of studies that are done, leading to gradual transitions in the types of problems worked on.

> When you are working with a customer and he is content about your work on, let us say food additives, and he wants a pesticide to be tested, then you don't say no. And the next time he asks for an environmental chemical to be tested, you also agree to do the tests. (Personal communication, H. B. W. M. Koëter, 24 September 1985).

In this way, not only the scope of chemicals that could be handled increased incrementally but the area of attention shifted. In CIVO, research on food-related chemicals gradually gave way to the testing of chemicals for a variety of industries. However, such resources were acquired at the price of constraints. The contract relation between industry and the institute ensured that test results are owned by industry. This fact constrains the possibility of using results from tests in the science system. The strategic choices made by industry directed the toxicologists who needed contract money. The overall interests of the chemical industry changed, and this change encompassed variations in the number of projects developed as well as the types of chemicals involved. Their willingness to make new investments determined the level of resources available.

The second example concerns toxicological research in the RIVM (State Institute for Public Health and Environmental Hygiene). The relationship between scientists and state officials relevant to this institution has been built up over the years, and the manner in which it has been structured depended on the stage of development of toxicology. Currently, the state provides all the resources of the RIVM, and relations with ministries are both crucial and constraining. The RIVM is not a contract laboratory for the ministries involved with health policy, but it is part of the ministries of Welfare Public Health and Culture (WVC) and Housing, Physical Planning and the Environment (VROM). The relation of the RIVM to the ministries is complicated. The RIVM director is represented at the highest political level in the ministry and is therefore able to influence health and environmental policies. However, the officials of the ministry influence RIVM decisions. Officially, they have to agree on the use of 80 percent of the research capacity; consequently, the ministries WVC and VROM form the main audiences for RIVM research plans.[12] Other ministries that have a relationship with the RIVM do not have such an immediate influence on the research programme.[13] This structural position of the RIVM implies that research efforts are judged by audiences that are in fixed relation with the scientists in comparison to CIVO discussed above. The manner in which these interactions evolved over time should tell us something about the manner in which reputational control is exerted.

In the early period, the problem of chemicals in the working and living environment of humans was not recognised by the state as a concern that warranted much investment. Scientists had to find ways to raise this interest. Later, when policy interest was present and relations with the RIVM became structured, a different sort of interaction resulted, and this can be systematically related to RIVM tasks. The method used by toxicologists to interest government in the early period consisted of creating alliances with other experts outside their own laboratory. Contacts with industrial toxicologists in the 1950s and 1960s supplied resources for government scientists. Industrial contracts provided the scientists with some financial means for their research: They were typically used to expand animal testing facilities and for the acquisition of specialised technical equipment (personal communication, H. Van Genderen Utrecht, 6 August 1985; 2 December 1985). The contribution in the form of research problems was perhaps more important than that of the link with industrial toxicologists. Toxicologists, to gain insight into the intricate details of safety testing, used new chemicals from industry. This experience, in turn, provided real problems on which fundamental research was based. For example, research observations on carcinogenicity in an industrial chemical led to research in carcinogenesis. Generally, research on industrial chemicals was used to impress government officials with the need to regulate chemicals. In short, safety evaluation under contract with industry was used as a lever to interest the government (personal communication, H. Van Genderen Utrecht, 6 August 1985; 2 December 1985). "The consciousness of the government with regard to toxicological research was raised, and the number of relevant questions from the government grew. The performance of contract testing became therefore less necessary" (personal communication, H. Van Genderen, 2 December 1985).

A second example illustrates the manner in which government attention can be attracted. To strengthen the capacity of the RIVM to tackle potential health problems caused by pesticides, the toxicologists set up alliances with scientists from other government institutes (e.g., the quality control bureau and the plant protection service) (Flipse 1969; personal communication, H. Van Genderen Utrecht, 6 August 1985; 2 December 1985). In the 1950s, the RIVM scientists took the initiative to draw together differently located scientists and some state officials to form a committee, the Committee on Phytopharmacy. This committee thus consisted of researchers and audiences and evaluated the health hazards of pesticides and agreed on spraying rules and pesticide residue levels on an informal basis. It was also active in an area that cut across the boundaries of the ministries dealing with health and agriculture.[14] Despite the lack of formal legislation, the committee dealt with pesticide problems, and the officials of the ministries responsible for agriculture and health did not appreciate this method of operating. These officials deemed it essential that a law on pesticides be introduced, in which the Phytopharmacy Committee was given official authority to evaluate the safety of new pesticides (personal communication, H. Van Genderen Utrecht, 6 August 1985; Flipse 1969).

> The functionaries saw toxicology as a way to deal with hazards by doing a few routine experiments. This attitude changed through the influence of the cooperation in the Committee on Phytopharmacy. Some of the civil servants developed a keen insight into the necessity of developing toxicological research. This new attitude made it possible to obtain sufficient means for toxicity testing and toxicological research. (Personal communication, H. van Genderen, 6 August 1985)

This episode shows the mechanism described in the previous section at work at the institutional level: Officials and scientists together structure the legislation and its content. In the formative phases, the insights of the scientists, mediated through joint committees, play an important role.

Both examples demonstrate the role of external groups in establishing an institutional reputation for toxicologists. With interests supported by external groups, research tasks envisaged at the working level become official tasks of the institute. They pervasively shape the relationships from the scientists with the ministry and with other social groups.

Conclusion

We have seen the embedded character of problem choice and institutional as well as reputational control in toxicology. Critical elements of both processes normally considered internal to science are shared with external groups. This sharing leads to hybrid structures.

Problem choice can follow theoretical lines whenever agreements with audiences allow science to proceed on a research agenda entirely set within the scientific community. The growth of toxicology suggests that from a practical and pragmatic start, increasingly more abstract and generalised research can find a place in the field. In developing such new activities, it is simpler to import knowledge, methods, and scientists from basic scientific fields. Through this mechanism, new fields that are added benefit from the relative autonomy of separate strands of research such as biochemistry. Basic scientific research on problems becomes the preferred solution whenever scientific fields are sufficiently detached from social concerns that they can set their own research agendas. However, within the overall framework of science, attention to social goals remains essential; that is, social usefulness, at a general level, allows for internal agendas at the field level.

The norms and standards of science are subject to change when clients and not scientific colleagues primarily judge the outcomes of research work. A difference exists in this respect between the early phases in Dutch toxicology and the later phases. In the first phase, research work and advisory duties were nearly inseparable. In the second phase, different functions of the arena, such as advisory work, policy formulation, and research, became separated. This division of tasks created strongly coupled groups: one of civil servants with toxicological training, an advisory establishment, and a group of scientists within research organisations. The civil servants draw up the policy agenda; the scientific advisers provide the civil servants with information and sanction their measures; the research workers are, in some cases, visibly present with the advisers and the civil servants in committees that coordinate research. Common practice also provided a crystallisation point for international scientific development. International scientific development provides groups in a local scientific community with increased status and enhanced legitimation. Thus, scientific communication in problem-oriented fields serves local groups in their own network. Localised scientific interest can, through long-term integration in international scientific publications and other means of exchange such as scientific associations, strengthen the position of scientists. Consequently, scientists can be regarded as impartial allies of the government or industry in solving problems. In hybrid fields, social recognition of problems, problem definition in the scientific sphere, and resource and audience structures merge.

That scientific autonomy has a negotiated character is shown to be relevant by others. Boundary conditions under which scientific research is performed are negotiable. When such boundaries are established, research organisations and audiences constitute a loosely knit system that is supported by multiple roles for all actors in the field. Audiences perform a role in providing resources and the legitimation of resources, and local actions by scientists are legitimated as contributions to problem definition and solution. The autonomy of scientists at specific locations in the field depends more on the links from these positions to other positions than the intellectual character of the work. In such hybrid scientific fields, processes of negotiation link choice of research problems and the availability of resources. Hybrid evaluation procedures shelter scientific research from too pervasive intrusion by outside social groups, enabling access to scientific resources and, at the same time, blocking easy access of competing scientific groups to specialised resources. In one sense, scientists use their science as a resource in the negotiation with outsiders (Latour 1987). The manner in which they proceed politically with this task is by making science opaque for outsiders. Thus, earlier findings on similar fields can be amended.

Salter has argued that the public aspect of toxicology and related disciplines, labelled as mandated science, poses a paradox for its practitioners. Their work is both highly public in the sense of being justified publicly, and less-than-public by the normal canons of science such as peer review (Salter 1988). Thus, mandated science often relies on an idealised picture of the scientific enterprise. Policy makers need science to be an idealised enterprise (e.g., value free, objective, independent of social interests, and highly rational to rely on science in the policy process). According to Salter, regulators and others in mandated science use the ideal picture of science to defend the role of science in regulation and proposed regulatory activities. In chaining in some activities and consequently avoiding interest group negotiations, scientific regulators are able to control some of the overt influence peddling and interest group negotiations that would otherwise have occurred (Salter 1988, pp. 197-98; Van Eijndhoven and Groenewegen 1991; Collingridge and Reeve 1986). Thus, the autonomy negotiated by the scientists allows the scientific research process to proceed within its own setting. Externally, the autonomy serves two purposes. It provides a role for scientists in the institutional setting around regulators and other decision makers, apart from other knowledge sources. Scientists are purposefully engaged in their roles as judge on facts and issues. Second, the engagement of scientists enables policy makers and regulators to disengage themselves from some of the social controversy surrounding the decision making on environmental and health hazards. To fulfil this role well, it is essential to embed the scientist's role in a process for scientific qualification, which only succeeds when the experts are engaged in scientific research. Therefore, research with a more global character also develops in institutional settings that are strongly supported by policy makers. This evolution of relative autonomous research in such institutional research settings as demonstrated in the emergence of Dutch toxicology is essential to relate the scientists to international science. International science provides the essential resource for both the scientists and regulators. From this conclusion, it can be inferred that development of applied scientific fields might lead to international scientific fields that help to set experts apart as scientists. They thus appear to be less the colonised group of experts that serves the wishes of policy makers as suggested by the concept of "epistemic drift" used by Elzinga (1988). The public function of toxicology is dependent on control by mixed fora. In the case of toxicology, it is not so much an existing discipline that bends to relevance and accountability pressures but in institutional, social, and cognitive terms, a separate effort is created. This effort has not only a social basis in a separate group of scientists working in different laboratories but it also has a cognitive dimension. Problems for policy makers cannot be mapped on a one-to-one basis on existing disciplinary research fields. It requires translation not only of the social but also of the cognitive dimension of the problem. The social engagement and the orientation to the solution of policy problems require a mutual structuring of policy and research agendas to arrive in this state. Thus, toxicology can be called a hybrid science in a double sense both cognitive and social (quality control and agenda setting).

The emergence of toxicology can be regarded as an example of a series of transformational steps in the societal role of science reflected in the analysis of the tension between scientific research and the demands of the social context in social studies of science. The first research and analytical efforts suggested a transition of the scientific research effort, from a separate social activity deemed necessary to establish a solid basis, to the development of applied research efforts. This transition has echoed in the concept of finalisation the Starnberg group in the 1970s (Böhme, Van den Daele, and Krohn 1973). The current discussion on the character of science vis-à-vis application points more to the effective transformation of science to a broadly used form of inquiry to support a wide variety of decisions, developments, and the solution of social problems (Gibbons et al. 1994).

Notes

1. Elzinga (1988) discussed three aspects of change in scientific research: (1) free flow of information diminishes; (2) research agendas get skewed in favor of particular social interests; and (3) researchers drift to commercial spheres or governmental stables. This argument is a normative one, and evidence for these assertions is lacking both from a political and critical perspective: "When research parks crop up, technology parks, sponsorship, and new university-industrial relations are put in place, it is mostly without much knowledge about the possible effects on the research system" (p. 5). Elzinga suggested two threats to science: (1) subversion of the specific "cognitive" or societal mission of disciplinary research and (2) quality control of the products of scientific work is diminished.

2. Historical examples have been discussed that are based on changes in the university research system (Geiger 1988; Blume 1987). It has been pointed out that academic researchers in the early twentieth century already held different opinions on the relation they should have with social constituencies (Rosenberg 1976; Servos 1981).

3. Cozzens (1986) argued that efforts to steer science have been neglected in science studies. In the theme issue that follows this introduction, resource availability linked to growth characteristics of scientific fields is used as the most dominant way of looking at these processes. While this is the dominant indicator used, in itself, the growth of knowledge is not necessarily a useful measuring device for assessment of the interaction between audiences and scientists. The mechanisms of interaction are but mostly only mentioned in passing. For example, Gillmor (1986) suggested for ionospheric physics a difference in the manner in which science is influenced by external organizations when these organizations choose funding people versus projects or problems.

4. For biotechnology, this has been analysed as one of the reasons for increased interaction with industry (Kenney 1986). Biomedical sciences also are strongly influenced by the changing interests of external funding agencies (Studer and Chubin, 1980). Agricultural sciences have been suggested to be particularly strongly bound to practice (Busch and Lacy, 1983).

5. The importance of "independent" scientific research and subsequent emphasis by scientists as well as policy makers on quality research has been analyzed in the framework of government support for science by Mukerji (1989).

6. Toxicologists are of course aware of this relationship, as the following quote demonstrates: "Regulation is thus an exploiter of toxicology; it relies on this scientific discipline to make social decisions. But regulators are not merely consumers of information that toxicologists generate. Regulatory programs have provided a major impetus for improvements in toxicologic studies" (Klaassen, Amdur, and Doull 1986, 34).

7. Every expert in the public health system soon converged on adulterated oil as the causative factor. Conclusive proof of what chemical factor in the oil was responsible was lacking, however.

8. One of the interesting aspects I will not go into detail on here is that regulatory toxicology would be an interesting field for a more detailed study of how social and scientific interaction is used to establish the essential steps for a good assessment. My suspicion, based on what I know of it, would be that it is a process characterized by sedimented layers of knowledge requirements

that were a result of either new problems to be solved or new scientific specialties that wanted to stake a claim in toxicology, some of which is outdated and most of which is a reflection of specific social problems with chemicals during the past forty years.

9. Contract research as a distinct form of scientific work has received only sparse attention in the sociology of science literature.

10. In this respect, it differed from other TNO (TNO-CIVO is a Dutch laboratory for food and nutrition research) institutes that were financed to a much larger extent by government money (up to 100 percent in some health- and defense-related institutes).

11. The decision to start toxicology was facilitated by the existence of a new building for animal experiments at CIVO (personal communication, A. P. de Groot, 20 May 1986; V. J. Feron, 7 August 1985).

12. The ministry had a small amount of money in the 1970s that it could spend outside the RIVM (State Institute for Public Health and Environmental Hygiene). However this money was taken away with the budget cuts in the 1980s. Accordingly, the ministry had to influence the research plans of the RIVM to get done the research it thought necessary (personal communication, F. W. van der Kreek, 1984).

13. The influence of political arrangements on the development of the RIVM can be seen in the cessation of research on occupational toxicology when the Directorate General of Labour was organized under another ministry. The ministry that at the moment shares responsibility with Welfare Public Health and Culture, that of Housing, Physical Planning, and the Environment, is also committed to the RIVM but has less influence on internal policy.

14. The scientists from various institutes were acting on the belief that they had to take responsibility themselves.

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